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JPRS Report

Science & Technology

Japan

NATIONAL AEROSPACE LABORATORY
1993-1994

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National Aerospace Laboratory 1993-1994

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[Introduction by Mr. Kazuaki Takashima, director-general of NAL]

[Text] **Introduction**

Our laboratory was founded as the National Aeronautical Laboratory in 1955, and the space division was incorporated into the newly-designated National Aerospace Laboratory (NAL) in 1963. Since then, NAL has conducted research and development related to aircraft, aeroengines and rockets. At the same time, NAL has directed its effort towards constructing large-scale test facilities for common use with other government organizations.

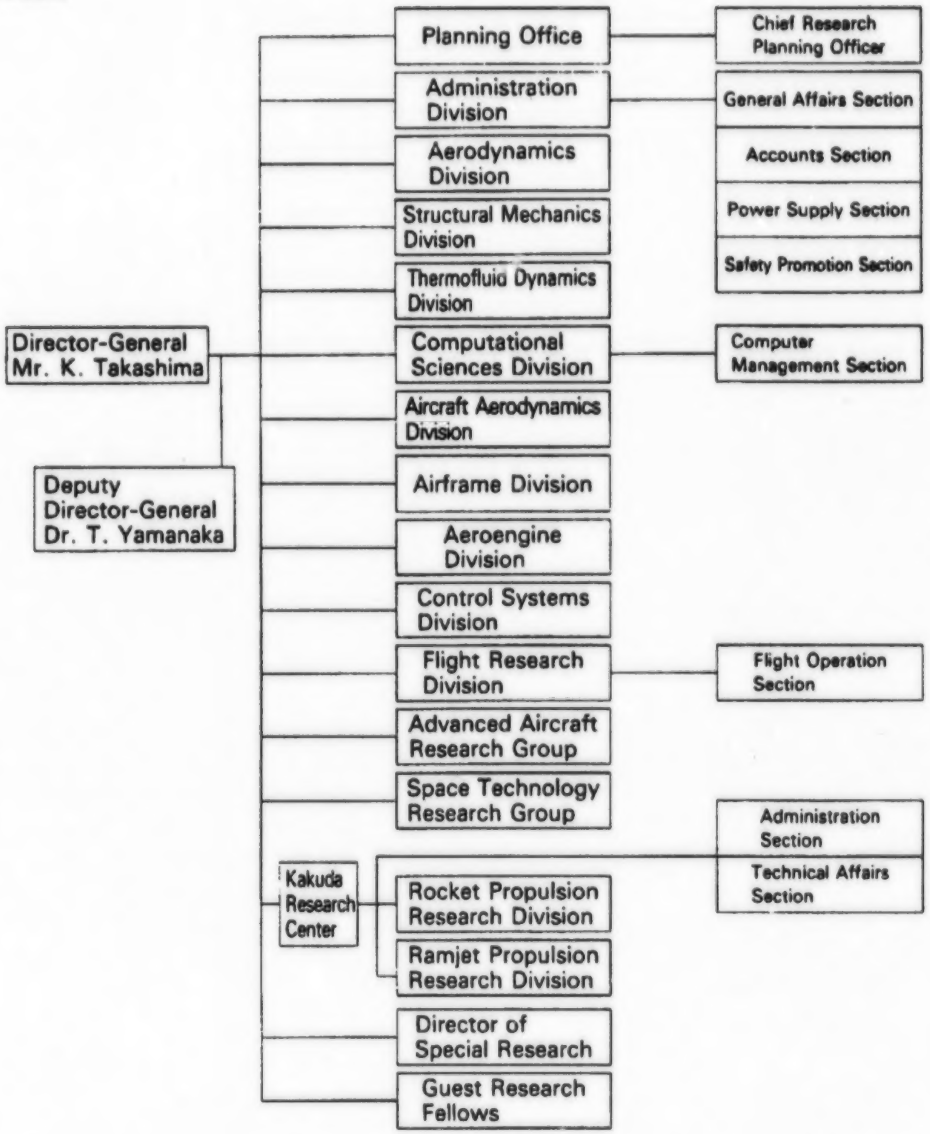
NAL's research activities have made many important achievements in the field of aerodynamics, material strength, structural mechanisms, aeroengines and control systems. In particular, the development of the STOL aircraft named "ASKA" is one of the major fruits of our laboratory. moreover, significant progress has been made in the effective utilization of test facilities and improvement of test methods.

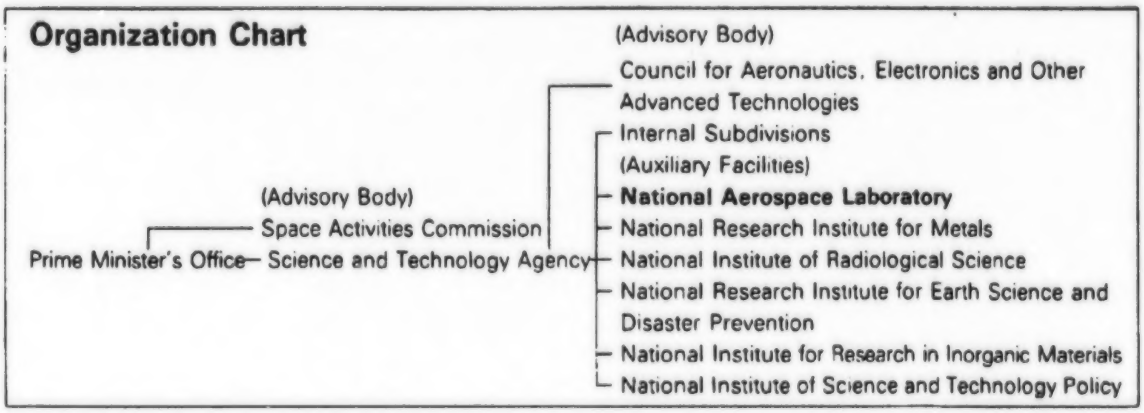
Since its foundation, NAL also has made technical contributions in almost all areas related to the development of aircraft, aeroengines and rockets in Japan. These activities have raised the level of japanese aerospace technology and, by introducing newly developed technologies, have contributed [to] the progress of aerospace technology worldwide.

Hereafter, in addition to continuing our research programs, greater emphasis is now being placed n the expansion of international cooperation.

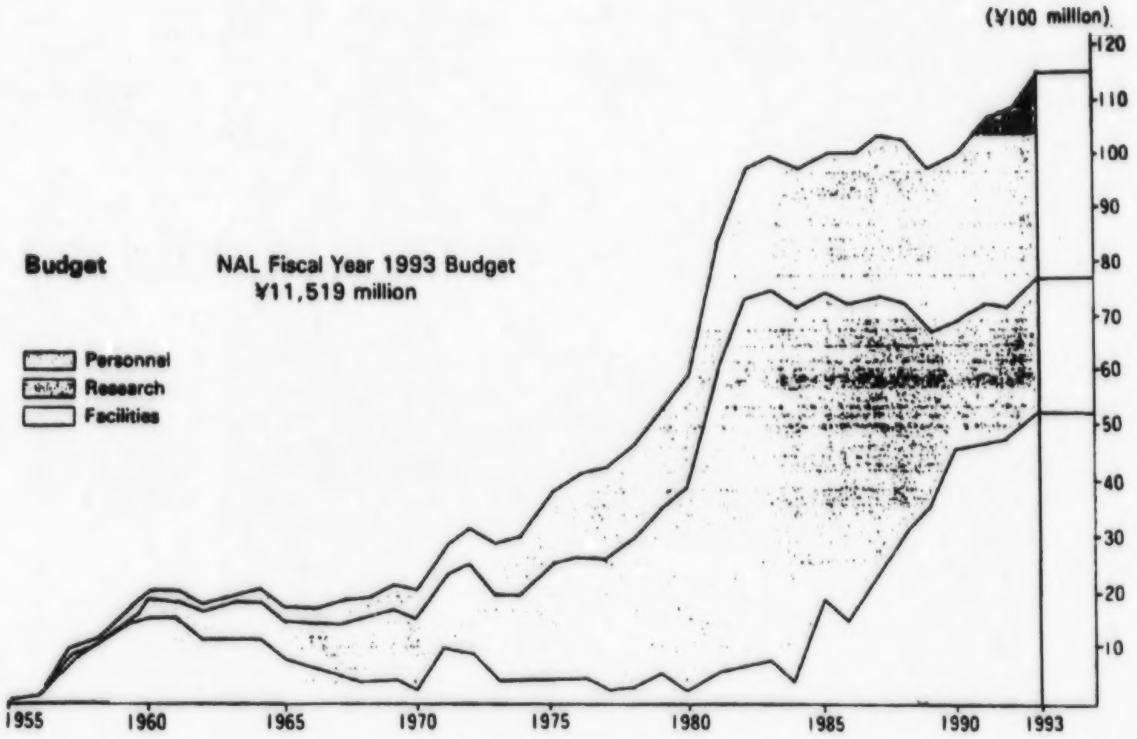
Aerospace technology involves many advanced research fields and is one of the systematically integrated technologies. As the 21st century approaches, it is expected that still greater emphasis will be placed on developments in aerospace for the betterment of mankind.

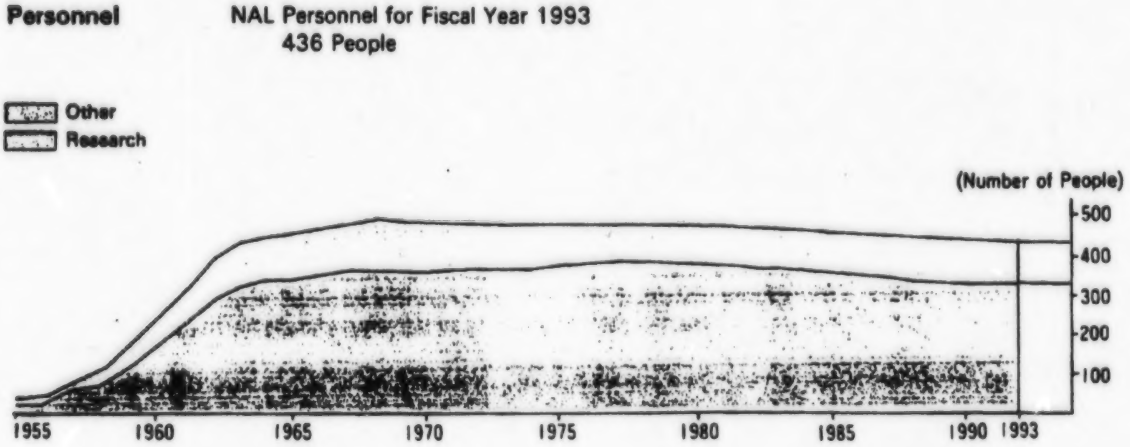
Organization



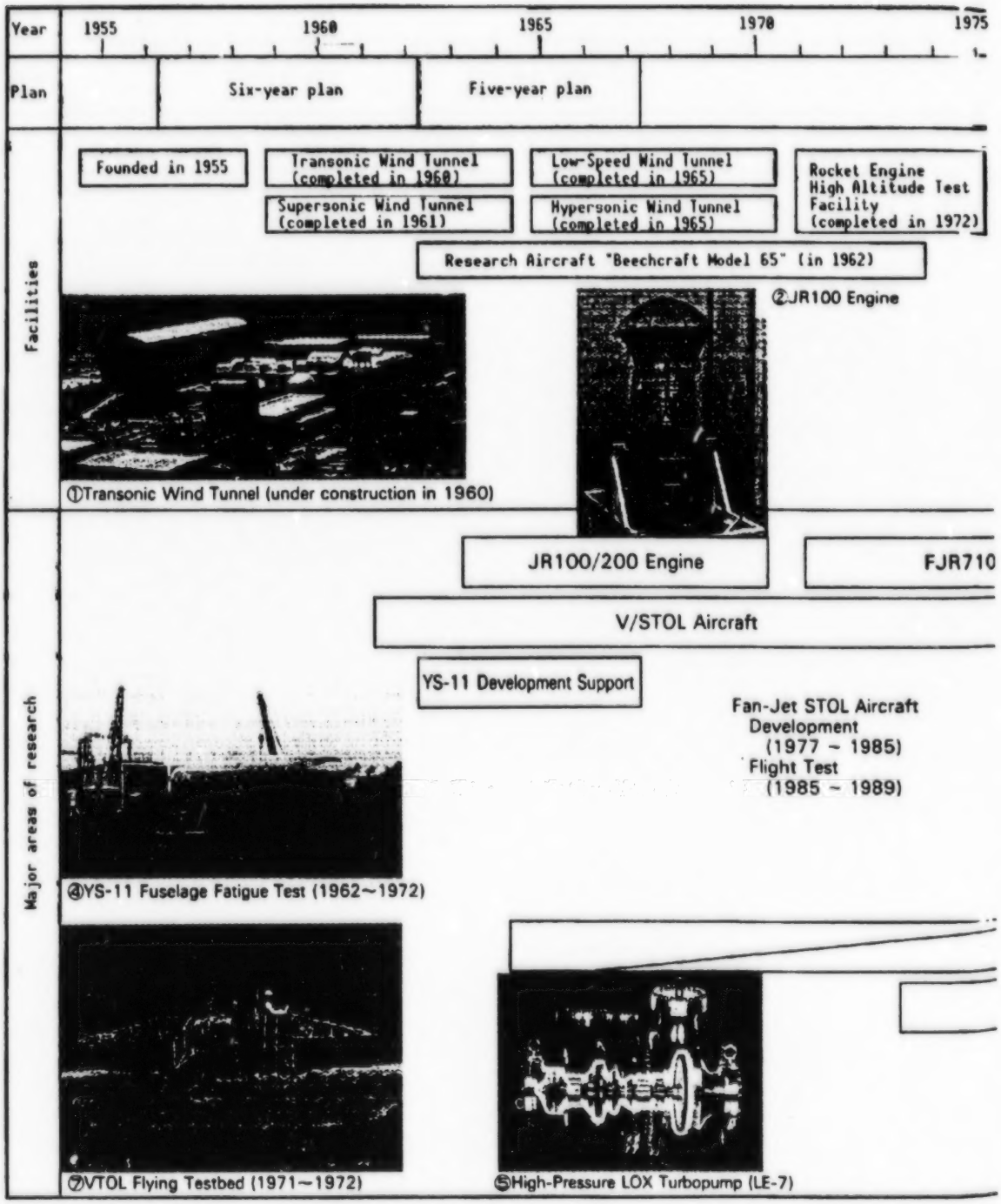


Budget and Personnel

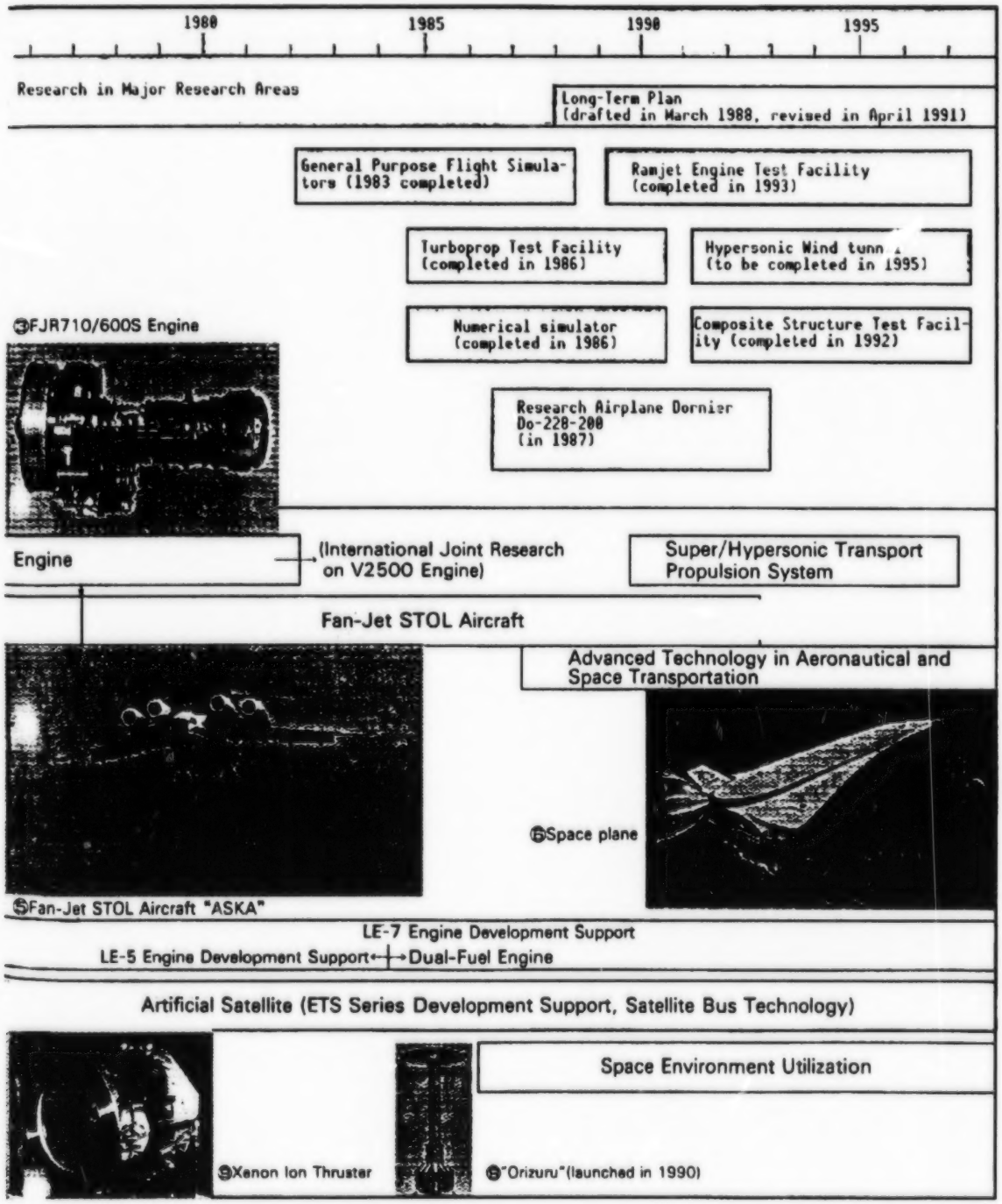




Major Areas of Research



[Continuation of Major Areas of Research]



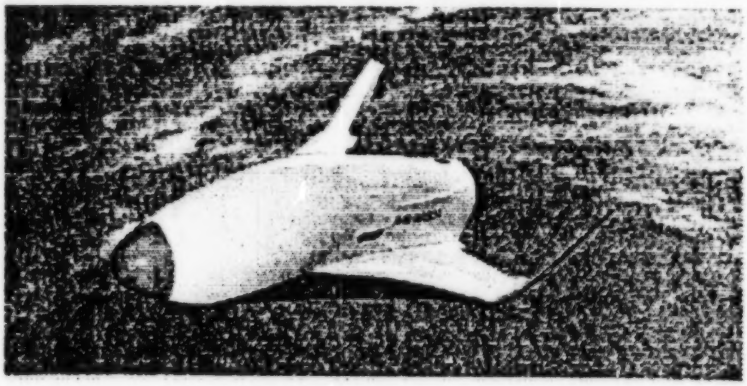
High Priority Research Projects

•[1] Research on HOPE (H-II Orbiting Plane)

The National Aerospace Laboratory, together with the National Space Development Agency, is studying an unmanned winged space vehicle called HOPE. HOPE will be launched by an H-II rocket, stay in space and perform winged return flight.

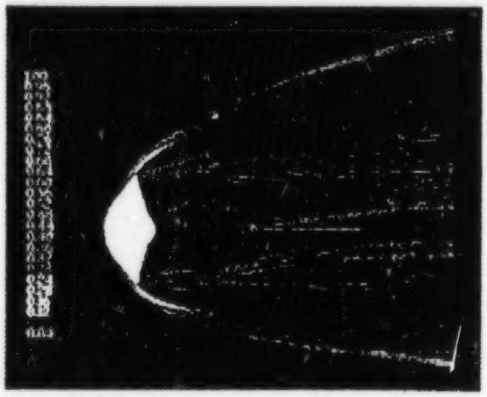
HOPE System Design Research

- •Aerodynamic design technologies
- •Heat-resistant material and thermo-structure technologies
- •Automatic landing and remote control technologies
- •Orbit maneuvering propulsion system technologies
- •Computational fluid dynamics technology

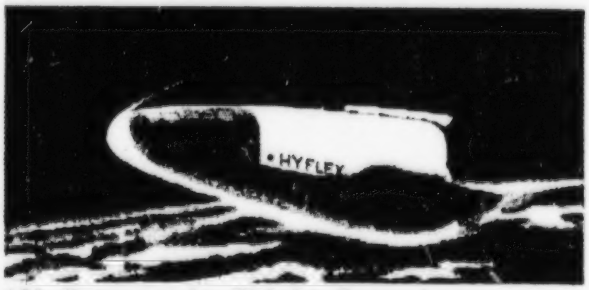


HOPE Test Vehicles

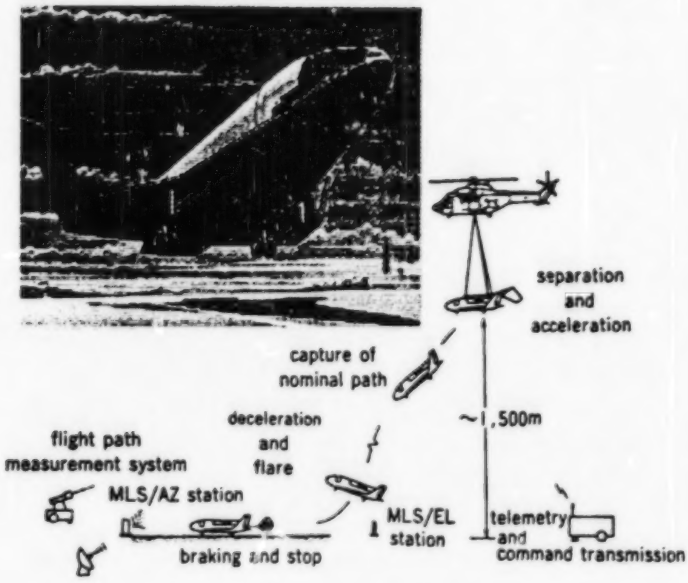
Three kinds of test vehicles (1, 2, 3) are prepared for data acquisition to develop the HOPE.

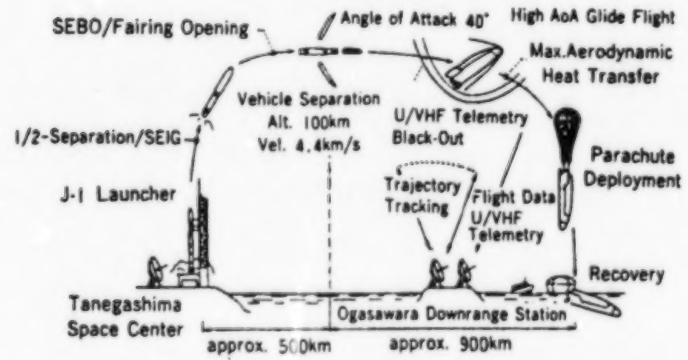


(1) Orbital Reentry Experiment (OREX)



(2) Hypersonic Flight Experiment (HYFLEX)





(3) Automatic Landing Flight Experiment (ALFLEX)

•[2] Spaceplane Research

Spaceplane is a new concept in manned space transport system in the 21st century. With the development of SSTO spaceplane, access to space directly from airports will be possible and NAL's technology program holds the key to this new concept.

System Concepts

- SSTO—A single-stage-to-orbit concept
- Horizontal take-off and landing like ordinary airplanes
- Comfortable, safe, and reliable space transport with reduced noise, vibration, and acceleration

Key Technologies

- Most advanced hypersonic propulsion system with liquid/slush hydrogen
- An integrated propulsion/airframe concept using advanced materials and structural designs
- Optimized aerodynamic/airframe concept using advanced materials and structural designs
- Advanced manned space flight technology
- Ability to abort safely at any point during the flight

R&D Program at NAL since 1987

- Extensive studies in system concepts and key technologies

- Test facilities for the scramjet engine, composite materials and hypersonic aerodynamics, and a supercomputer complex for numerical simulation.

[Photo caption] NAL is developing the Ramjet Engine Test Facility and a subscale scramjet engine—a vital technology in the development of the SSTO Spaceplane (photo: supersonic combustion experiment [not reproduced])

•[3] Advanced Aircraft Technology Research

Towards the next century, advanced high-subsonic aircraft which offer energy efficient, massive/long-haul payload delivery is expected to emerge.

To this end, the following innovative key technologies in the relevant fields are being investigated.

• Aerodynamics	Laminar flow control, advanced configuration aerodynamics
• Structures/structural dynamics	Thermoplastic composite materials/structures, aeroelastic tailoring
• Flight control	Active control technology, intelligent controls
• Propulsion	Ultrahigh bypass-ratio/variable geometry engine
• Systems	Conceptual study of advanced configuration aircraft

[Captions of photos not reproduced]

1. Visualization of the boundary-layer transition over a laminar-flow-control wing with suction. (Inset shows enlarged photo of the suction surfaces).

2. First CF/thermoplastic wing box model.

3. Semi-free flight experiment to study gust load alleviation for a complete ACT aircraft model supported by an active suspension system.

4. Ducted fan aerodynamic model used to confirm design methods by computational fluid dynamics.

5. Future VTOL transport concept installed with very quiet lift fan engine system.

•[4] LO_x/LH_2 Rocket Engine Research

The liquid oxygen (LO_x)/liquid hydrogen (LH_2) rocket engine has the highest performance of any rocket engine. NAL has made major contributions to the development of LO_x/LH_2 rocket engines in Japan.

A research program to establish component technology for advanced high-performance rocket engines such as dual-fuel rockets is under way.

[Captions of photos not reproduced]

1. LE-7 high pressure LO_x turbopump test.

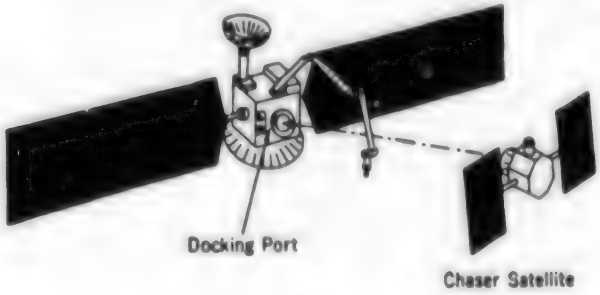
2. LO_x/LCH_4 combustor test.

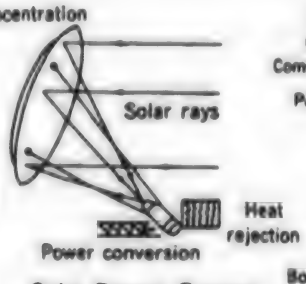
•[5] Research on Basic Spacecraft Bus Technologies

To meet future requirements for more complex space missions and to advance space activities, research in particular areas of basic spacecraft bus technology is being encouraged.

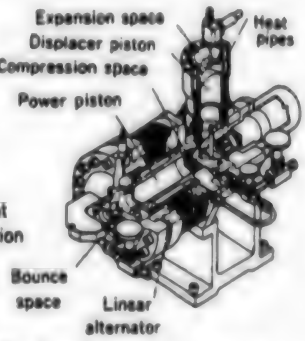
Rendezvous/docking technology, and in-orbit operation
Establishment of common basic technologies necessary for assembly of large structures in orbit, and exchange and maintenance of satellite components

Technology for solar power system
Establishing a technological basis to realize a highly efficient solar dynamic power system in orbit





Solar Power System



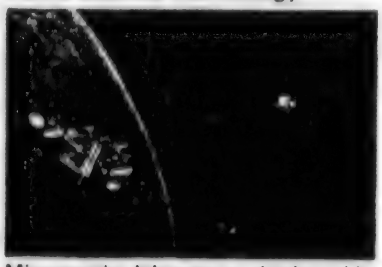
Stirling Engine/Alternator Model

•[6] Research on Space Environment Utilization Technologies

Space environment utilization is a new field of research which has already received much attention worldwide and which is expected to advance with the future International Space Station Program.
The aim of NAL's work in this area is to establish the technological foundation for space environment utilization experiments.

A Better μG Environment

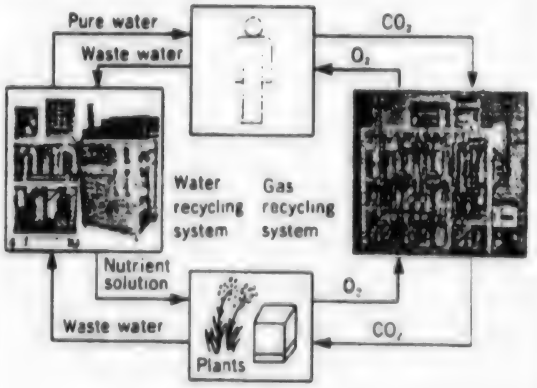
· Tether Satellite Technology

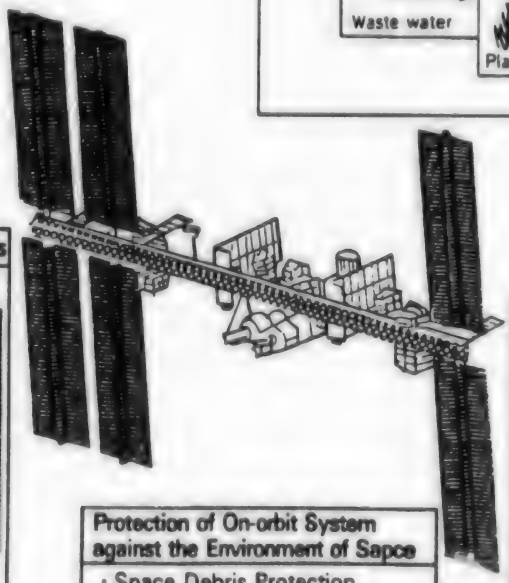


Microgravity laboratory deployed in the proximity of space station.

Effective Utilization of Onboard Resources for Life Support

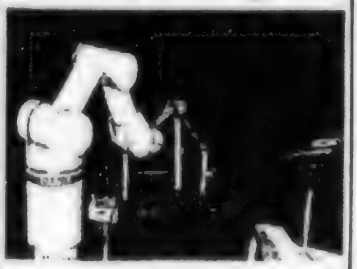
· Gas and Water Recycling Technology





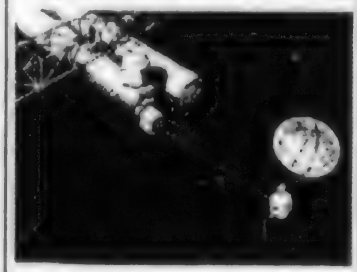
More Flexible Operation Capabilities

· Telescience Technology



Structure construction using a tele-operated robot arm

· Deployable Test Bed Technology



To provide wide working area and field of view.

Protection of On-orbit System against the Environment of Sapce

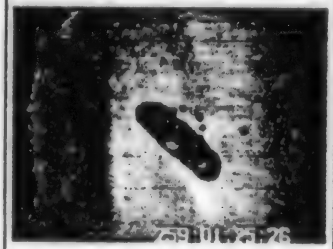
· Space Debris Protection Technology

Hypervelocity impact experiment

To Study Phenomena in Microgravity

· Fluid Dynamics in a μG Environment

Experiments on bubble behavior under a thermal gradient



Oil drop perturbed by sound waves

•[7] Research on Numerical Simulation Technologies

Numerical simulation technology is a key research and development technology in the field of aeronautics and astronautics, which has been advancing rapidly together with the evolution of ultrahigh-speed computers. NAL's efforts are devoted to the research and development of numerical simulation technologies for aerodynamics, thermofluid dynamics and structural mechanics based on the results of studies on mathematical and numerical analysis, parallel computers, and image processings.

The developed software packages are effective design tools for aircraft and spacecraft in Japan.

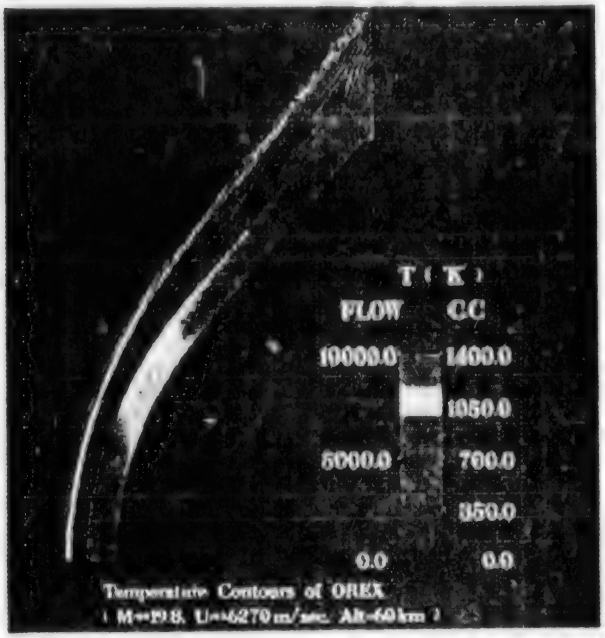


Fig.1 Numerical simulation of hypersonic reacting flow around OREX.

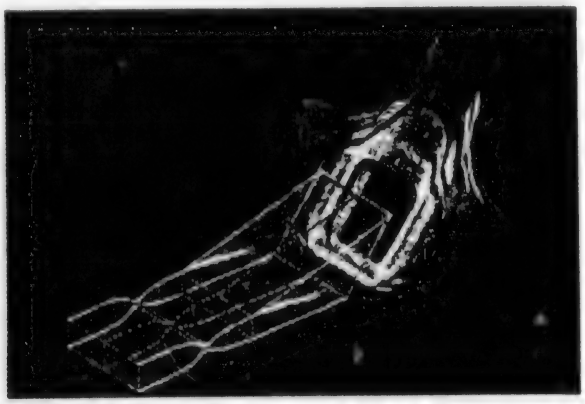


Fig.3 3-D Navier-Stokes analysis of flow through nozzle of scramjet engine.

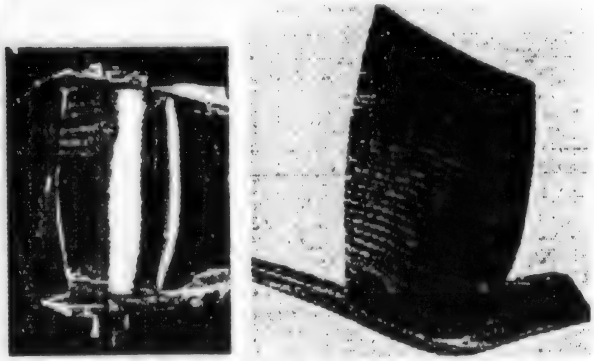


Fig.4 Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design.

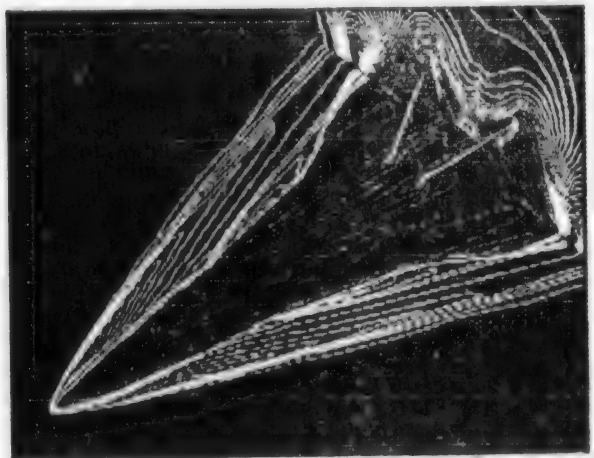


Fig.2 Numerical simulation of supersonic flow around a spaceplane model.

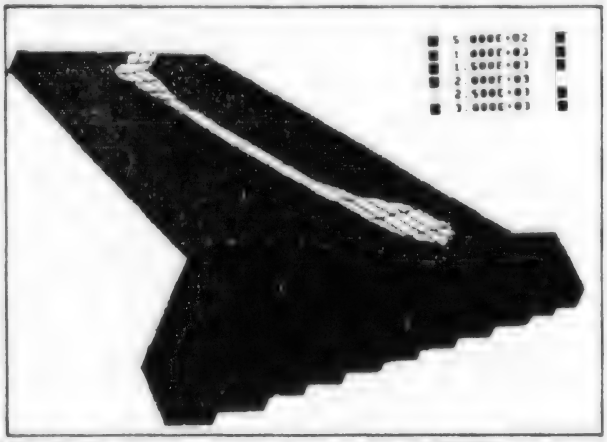


Fig.5 Thermo-response simulation of OREX onboard sensor mount.

Joint Research, Contract, Facilities

NAL is conducting a number of joint research [projects] with other laboratories and private companies. NAL allows its test facilities to be utilized by other organizations to promote aeronautical and space technology.

1. Wind Tunnels

NAL's test facilities include the following large-size wind tunnels where tests are conducted at low to hypersonic wind speeds.

	Speeds	Test-section size	Type
Low-speed wind tunnel	1m/s~60m/s	6.5m x 5.5m	Continuous
Transonic wind tunnel	Mach 0.1~1.4	2.0m x 2.0m	Continuous
Supersonic wind tunnel	Mach 1.4~4.0	1.0m x 1.0m	Intermittent blowdown
50cm hypersonic wind tunnel	Mach 5,7,9,11	ϕ50cm	Intermittent blowdown
1.27m hypersonic wind tunnel (under construction)	Mach 10	ϕ1.27m	Intermittent blowdown

2. Numerical Simulator

The numerical simulator is composed of a jointly developed large-scale parallel supercomputer (NWT) and VP2600 which is used as a front end processor. This powerful system makes possible simulations of flow around aircraft/spacecraft and of engine internal flow. It is also utilized for simulations in the fields of structure and control.

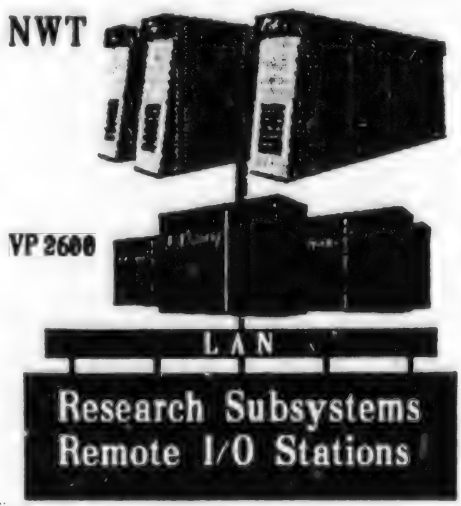


Figure 1. Configuration of Numerical Simulator

3. Facilities for Structure and Material Research

Structural testing facilities are continuously being built for strength tests of domestic aircraft and rockets. Moreover, composite structure testing facilities were built recently to conduct advanced structural and materials research activities for aircraft, supersonic transports (SST), and space transportation systems.

4. Test Facilities for Engine Research

(1) Aircraft Engine Test Facilities

NAL has various test facilities for the research and development of super/hypersonic propulsion systems and high-subsonic VTOl engines. These facilities include cascade, cooling, and structure test facilities for basic research; air-intake, fan/compressor, combustor, turbine, nozzle, control/instrumentation and ramjet combustor test facilities for component research; and engine test cell and noise test facilities for system research.

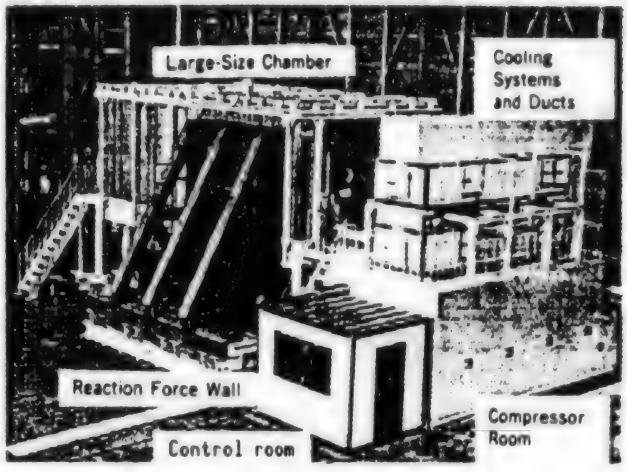


Figure 2. Large-Size Environmental Chamber System for Composite Structure Testings

(2) Ramjet and Rocket Engine Test Facilities

At the Kakuda Research Center, various test facilities for rocket engines have been built for use in the development of many Japanese rocket engines, including the LE-5 and LE-7. The Ramjet Engine Test Facility becomes operational in FY1993.

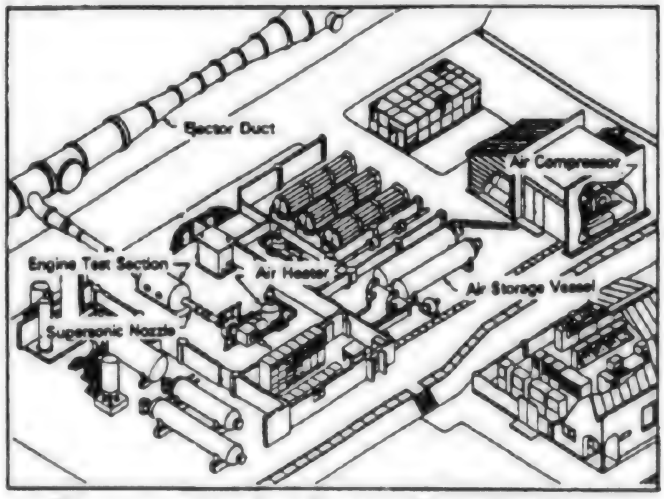


Figure 4. Ramjet Engine Test Facility

5. Flight Simulator

Sitting in a faithfully simulated cockpit and steering a control wheel, the flight simulator motion base and visual system combine to produce real-flight body sensations. A general purpose flight simulator is used for research on advanced aircraft or for design modifications of existing aircraft.

A helicopter simulator is used for research on operational safety of helicopters.

6. Research Aircraft for Flight Experiments

Flight experiments are necessary for research related to the flying characteristics such as stability and control. This research is conducted using two research aircraft: a twin piston engine aircraft (Beechcraft model 65) and a twin turboprop engine aircraft (Dornier Do-228-200). The Beechcraft

model 65 has been equipped with a specially developed flight control system which includes a Direct Lift Controller (DLC) and has been modified for use as a Variable Stability and Response Airplane (VSRA) for in-flight simulations.

[Captions of photos not reproduced]

Figure 3. Engine test cell (capacity: 100 kN)
Figure 5. Research flight simulator
Figure 6. Beechcraft model 65 (foreground) and Dornier Do-228-200 (background)

Aerodynamics Division

Organization

Aerodynamics Division	—Engineering Lab. —Hypervelocity Aerodynamics Lab. —Rarefied Gas Dynamics Lab. —High Enthalpy Flow Lab. —Separated Flow Lab. —Viscous Flow Lab. —Shock Tunnel Lab. —Hypersonic Wind Tunnel Facilities Lab. —Hypersonic Wind tunnel Instrumentation Lab. —Supersonic Wind Tunnel Facilities Lab. —Supersonic Wind Tunnel Instrumentation Lab.

Major Areas of Research

In the Aerodynamics Division, high priority research is being carried out in areas such as winged space vehicle study and CFD (Computational Fluid Dynamics) technology development, focusing on the hypersonic and supersonic aerodynamic aspects. Also construction of an extension to the existing hypersonic wind tunnel to provide a larger test core (nozzle exit diameter of 1.27m) is now under way.

In addition, the following research subjects are also in progress.

1. Hypersonic flow experimental and numerical investigations
2. Rarefied gas dynamics and high-enthalpy flow
3. Turbulent, viscous, and separated flow
4. Shock tunnel utilization techniques
5. Control and instrumentation of hypersonic wind tunnel
6. Control and instrumentation of supersonic wind tunnel

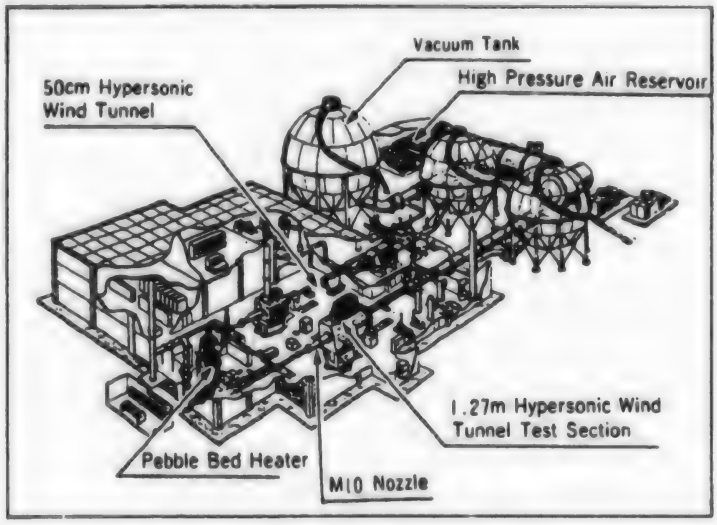


Figure 2. 1.27m Hypersonic Wind Tunnel (Under Construction)

Figure 1. Numerical Simulation of Rarefied Flow Around a HOPE Model (Temperature distribution at $M_\infty=25$, $Kn_\infty=1$, $T_w=T_\infty$)

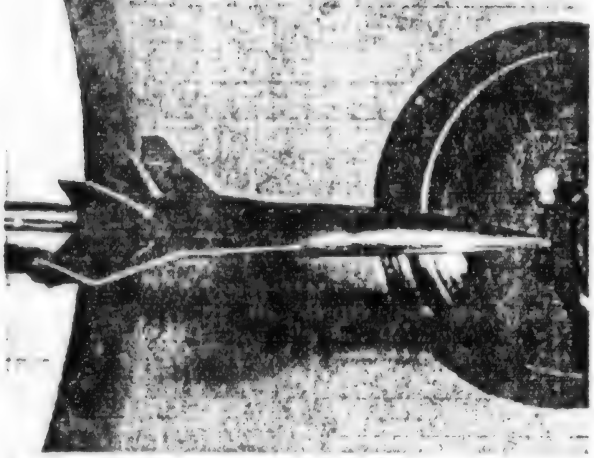


Figure 3. Hypersonic Wind Tunnel Test of an Aerospace Plane Model

Structural Mechanics Division

Organization

Structural Mechanics Division	—Engineering Lab. —Aeroelasticity Lab. —Thermostructure Lab. —Structural Dynamics Lab. —Fracture Mechanics Lab.

Major Areas of Research

The Structural Mechanics Division is responsible for basic research on the behavior of materials and structures as well as numerical simulation techniques as they relate to the research projects on innovative aerospace transportation technologies.

Typical research subjects are as follows:

1. Aeroelasticity
2. Mechanics of thermal protection structures
3. System identification of aerospace structures
4. Fracture strength of structural components

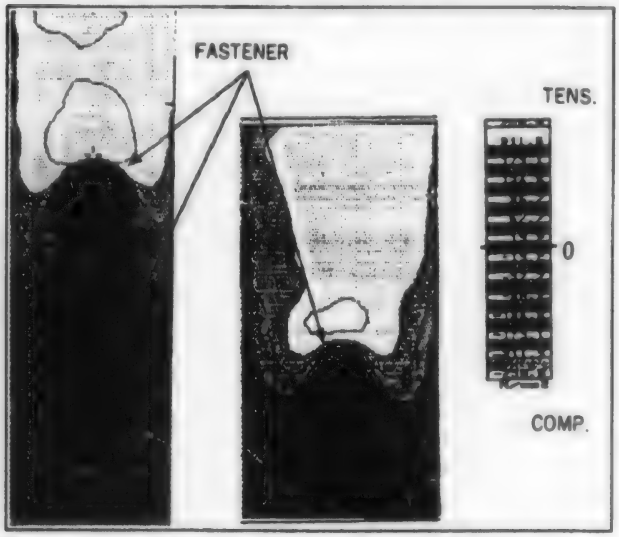


Figure 4. Stress Flow Around Fastener Joint of Aerospace Structures

[Captions of photos not reproduced]

Figure 1. Wind tunnel test for flutter characteristics evaluation at transonic region.

Figure 2. Radiant heating test for actively cooled thermal protection panel.

Figure 3. Scale model vibration test of H-II launch vehicle.

Thermofluid Dynamics Division

Organization

Thermofluid Dynamics Division	—Engineering Lab. —Aeroacoustics Lab. —Reacting Flow Dynamics Lab. —Computational Thermofluid Dynamics Lab. —Heat Transfer Lab.

Major Areas of Research

The Thermofluid Dynamics Division is responsible for research on thermal and fluid dynamic phenomena in aerospace propulsion systems.

Research and development on supersonic transport propulsion systems has also been in progress since 1990 in cooperation with the Agency of Industrial Science and Technology. Fundamental research on emissions is also under way in cooperation with the Environment Agency.

Other research includes:

1. Aircraft/engine noise reduction and turbomachinery unsteady flow
2. Gas turbine emission reduction
3. Propulsion numerical simulation and applications
4. Heat transfer in gas turbine hot parts

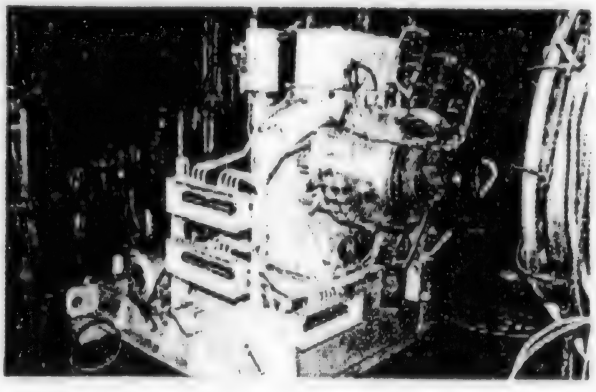


Figure 1. Gas Turbine Engine Used for Low-Emission Combustion Research

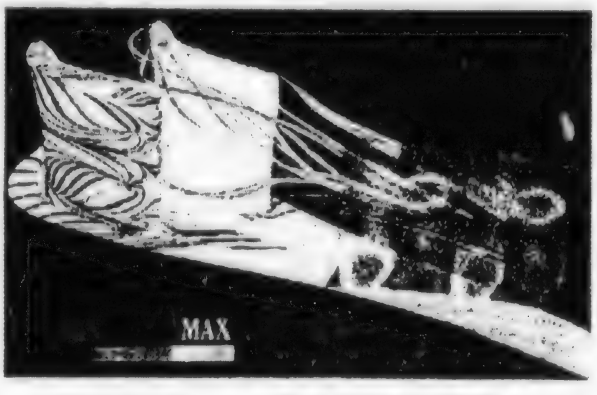


Figure 2. Numerical Simulation of Tip Clearance Flow of a Turbine Rotor

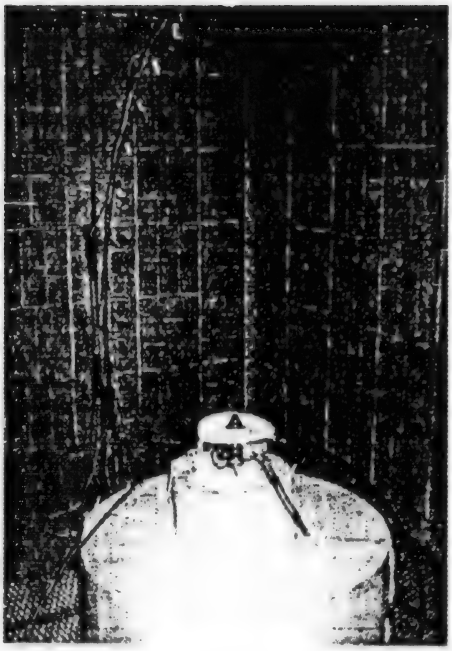


Figure 3. Supersonic Jet Noise Test Facility

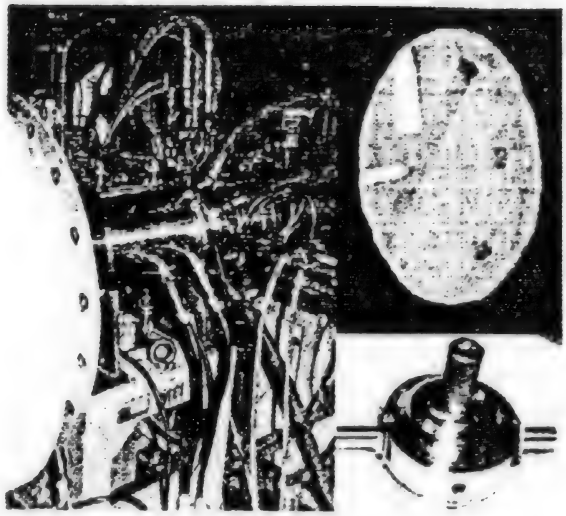


Figure 4. Hot Spin Tester, Its Inlet Section Under Burning and Rotating Part

Computational Sciences Division

Organization

	—Computation Lab.
	—Data Processing Lab.
Computational Sciences Division	—Numerical Simulator Lab.
	—Applied Mathematics Lab.
	—Parallel Processing Lab.
	—Computer Management Section

Major Areas of Research

Research activities in the Computational Sciences Division are focused on numerical simulation technology, ranging from basic to applied, which is now a key technology in research and development in the field of aeronautical and space technology.
Research on applied artificial intelligence and image processing is also being conducted. Additionally, the Computational Sciences Division is responsible for the management and operation of the Numerical Simulator.

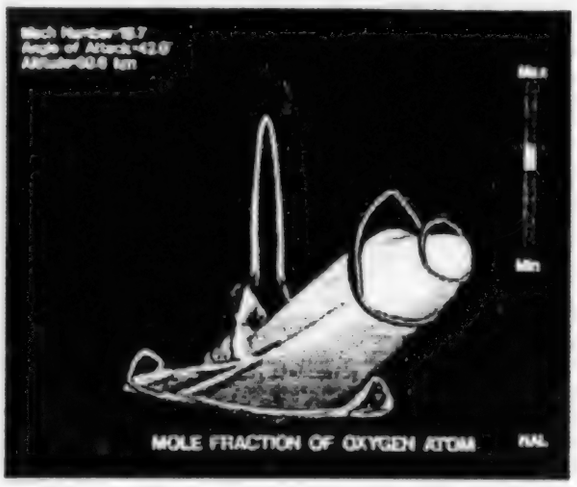


Figure 1. Distribution of Dissociated Oxygen Atoms Around a Spaceplane (Altitude=60.6km, Mach No.=15.7, Angle of attack=42°)

1. Numerical simulation
   - Partial differential equations and difference approximations
   - Computational aerodynamics for aircraft/spacecraft
   - Computational fluid dynamics for jet engines and ram/scram engines
   - Numerical structure simulation
   - Parallel processing
   - Numerical simulator systems

2. Applied artificial intelligence
   - Knowledge-based systems
   - Telescience technology

3. Image processing
   - 3-D image processing systems
   - Multimedia information systems
   - Vision systems

Figure 2. Oceanographic Patterns Extracted by Using a Knowledge-Based Satellite Image Processing System (Off the coast of Sanriku)

Aircraft Aerodynamics Division

Organization

Aircraft Aerodynamics Division	—Engineering Lab. —Full Configuration Aerodynamics Lab. —Computational Aerodynamics Lab. —Low-Speed Aerodynamics Lab. —Control Surface Aerodynamics Lab. —Unsteady Aerodynamics Lab. —Aerodynamics Testing Techniques Lab. —Transonic Wind Tunnel Facilities Lab. —Transonic Wind Tunnel Instrumentation Lab. —Low-Speed Wind Tunnel Facilities Lab. —Low-Speed Wind Tunnel Instrumentation Lab. —Two-Dimensional Transonic Wind Tunnel Lab.

Major Areas of Research

The Aircraft Aerodynamics Division is concerned with aerospace vehicle aerodynamics at speeds ranging from take-off and landing to transonic speeds. This division is also responsible for maintenance and improvement of the major low-speed and transonic wind tunnels at NAL. Its research efforts are currently directed in the following areas:

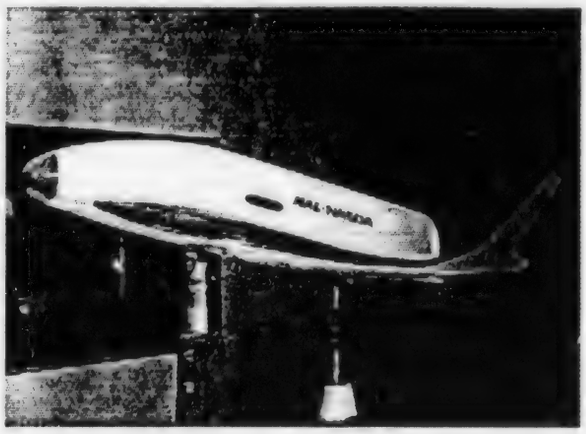


Figure 1. HOPE Landing Characteristics Test at the 6.5m x 5.5m Low-Speed Wind Tunnel

1. Improving wind tunnel testing techniques to enhance the reliability in data acquisition and the efficiency in operations as well as to accommodate the ever-increasing variety of test articles.

2. Studying flow mechanisms such as the boundary-layer transition and separation to advance the basic knowledge for improving vehicle performance, and

3. Promoting the development and utilization of CFD techniques to augment vehicle aerodynamical design capabilities and to explore their ability as tools for studying flow mechanisms.

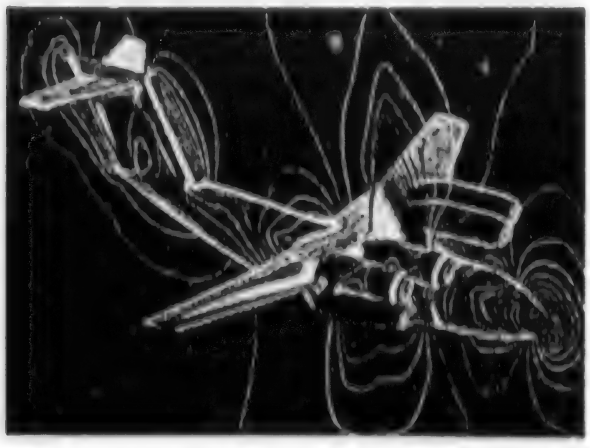


Figure 2. CFD Analysis of the Flow Around the STOL Experimental Aircraft ASKA

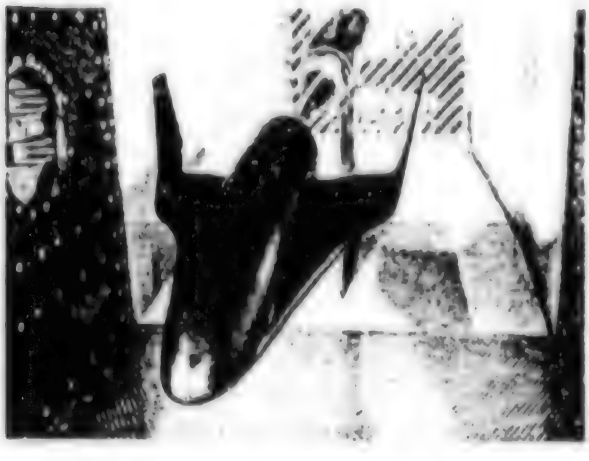
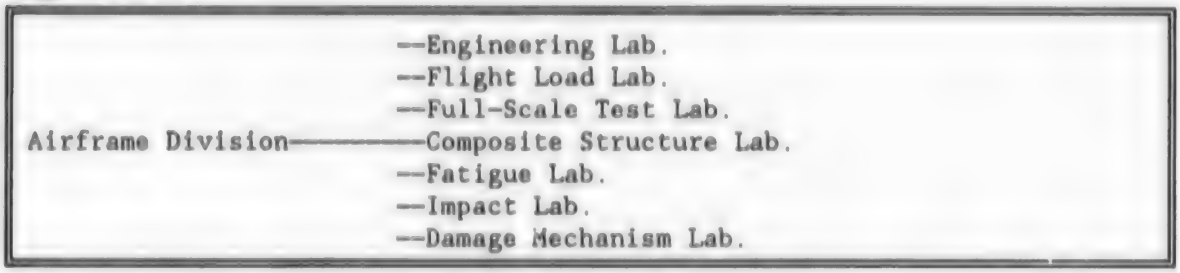


Figure 3. Test of a HOPE Model at the 2m x 2m Transonic Wind Tunnel

Airframe Division

Organization



Major Areas of Research

The Airframe Division conducts research on advanced composite materials and structures related to space transportation and innovative aeronautical technologies as high priority projects. Research and investigation on aircraft accidents are also conducted at the request of the Aircraft Accident Investigation Commission.

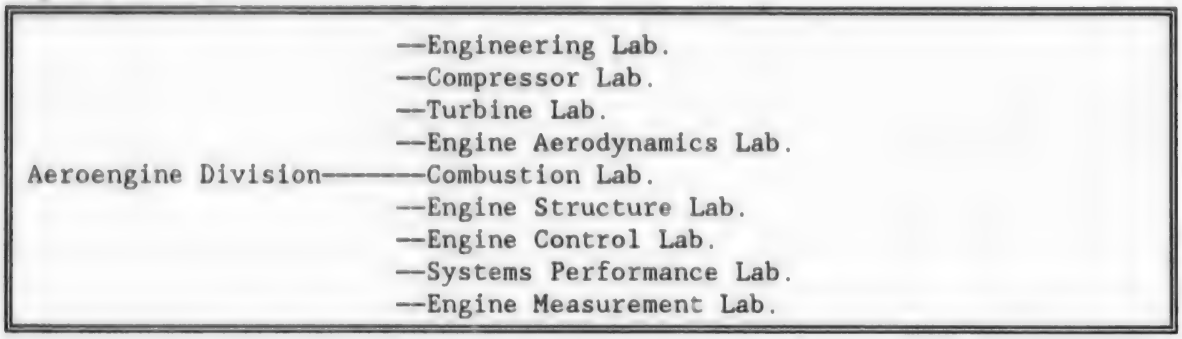
1. Research on structures of winged re-entry vehicles
2. Reliability-based safety evaluation of damage tolerant structures
3. Composite strength
4. Reliability evaluation of static and fatigue strength of structural materials and components
5. Airframe impact strength
6. Structural component damage evaluations

[Captions of photos not reproduced]

Figure 1. Vibration test of a tip-fin flutter model using the dynamic displacement measurement system
Figure 2. Ambient tensile test of oxidation-resistant ceramic composites for use at high temperatures (high strength: 400 MPa)
Figure 3. Fatigue damage of composite laminate under biaxial cyclic loads

Aeroengine Division

Organization



Major Areas of Research

The Aeroengine Division conducts research on the ultrahigh bypass-ratio variable geometry engine, which is one of the high priority research [projects] in the field of high-subsonic aircraft engines, and on the research of supersonic propulsion system technology as a part of the National Research and Development Program promoted by the Agency of Industrial Science and Technology. This division is also concerned with the research of the airbreathing engine in the field of space transportation. Research is also being conducted on component technology of ceramic gas turbines as part of the "New Sunshine" Project.

Other research subjects are:

1. Overall performance of propulsion systems
2. Turbo-machinery and fluid mechanics
3. Advanced fans and compressors
4. Advanced gas turbine combustor design
5. Highly-loaded and high-efficiency turbines
6. Advanced engine control and instrumentation
7. Engine structures and materials
8. Measurement methods of internal flow

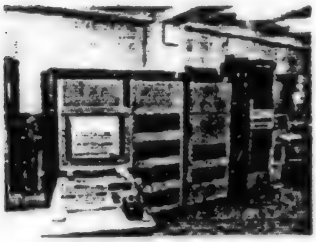


Fig. 1 Engine Simulator: AD 100 System

Evaluation of Advanced Materials

Fig. 2 Measurement of FRP Blade Deformation by Laser Holography

High-subsonic Aircraft Engine

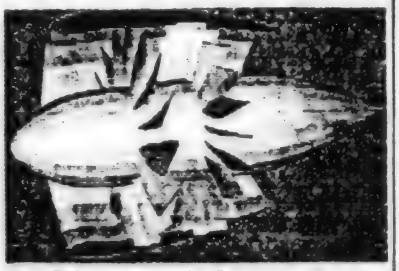


Fig. 3 Ultra High Bypass-Ratio Engine

Super/Hypersonic Transport Propulsion System

Engine for Spaceplane

Fig. 4 Air-Turbo Ramjet

Intake, Fan, Compressor, Combustor, Turbine, Exhaust Nozzle, Control

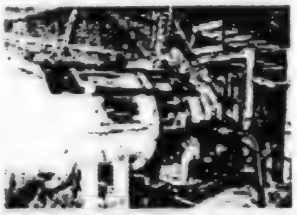


Fig. 5 Turbo-machinery Component Research

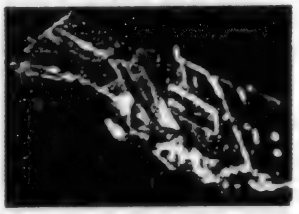


Fig. 6 Mach 3 Air-intake Model

Fig. 7 Ram Combustor Test for Hypersonic Plane

Control Systems Division

Organization

Control Systems Division	—Engineering Lab. —System Control Lab. —Instrumentation Lab. —Aerospace Instrument Lab. —Guidance and Control Lab. —Flight Simulation Lab. —Human Engineering Lab.

Major Areas of Research

The Control Systems Division has given high priority to research on guidance and control systems for the spaceplane and intelligent flight control systems for aircraft. In addition, the following research is being conducted.

1. Flight control systems research
   - Innovative control and estimation technology
   - Remote control and control systems
   - Aerospace navigation and mission technology

2. Measurement and instrumentation research
   - Satellite applications (GPS etc.)
   - Advanced inertial navigation sensors and systems
   - Remote-sensing instruments for earth observation

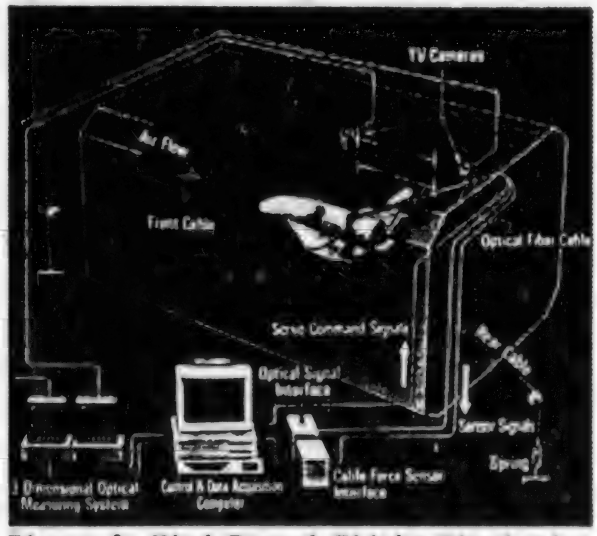


Figure 3. Wind-Tunnel Flight Simulation Experiment for a HOPE Model

3. Flight simulator systems research
   - Aircraft and spaceplane simulation
   - Flight simulator systems
   - Wind-tunnel flight simulation technology

4. Human factors research
   - Operational safety of airplanes and helicopters
   - Intelligent cockpit systems

[Captions of photos not reproduced]

Figure 1. Experimental model of an imaging spectrometer
Figure 2. Transport simulator cockpit

Flight Research Division

Organization

Flight Research Division	—Engineering Lab. —Flight Qualities Lab. —Flight Test Lab. —Flight Research Management Lab. —Flight Instrumentation Lab. —Flight Analysis Lab. —Flight Operation Section

Major Areas of Research

The Flight Research Division is responsible for conducting flight experiments and evaluating flight test methods for research related to flying characteristics, navigation, and guidance and flight control systems. This research is conducted using two research airplanes: a twin piston engine airplane (Beechcraft model 65), and a twin turboprop light transport (Do-228-200).

1. Navigation and guidance system evaluation with the Dornier Do-228 and feasibility studies for its modification to an in-flight simulator.
2. Flying characteristics of variable stability and response aircraft (VSRA).
3. Automatic landing system for re-entry space vehicles.
4. High precision guidance system using a head-up display.
5. Real-time flight test data analysis and monitoring systems.
6. Optimal flight control system that is robust against vehicle's dynamic change.
7. Helicopter flight dynamics.
8. Flight dynamics simulation.
9. Powered lift technology.
10. Flight operation.

Figure 3. In-Flight VSRA Simulation

[Captions of photos not reproduced]

Figure 1. Flight test by head-up display (HUD)
Figure 2. Basic flight test of HOPE using Do-228

Advanced Aircraft Research Group Organization

Advanced Aircraft Research Group	—Group No. 1 (Planning and Engineering) —Group No. 2 (HOPE Research Planning and Coordination) —Group No. 3 (HOPE System Planning) —Group No. 4 (HOPE Experiment Planning) —Group No. 5 (Spaceplane Optimal Configurations) —Group No. 6 (New Configuration Aircraft Performance) —Group No. 7 (New Configuration Aircraft Optimal Configurations) —Group No. 8 (Powered Lift Aircraft Performance) —Group No. 9 (Active Control of Aeroelastic Systems) —Group No. 10 (Advanced Flight Control Systems) —Group No. 11 (Gust Wind Tunnel Testing)

Major Areas of Research

The Advanced Aircraft Research Group is responsible for research related to HOPE, spaceplane, powered lift aircraft, and new configuration aircraft. The research on aircraft covers active control technology such as flutter suppression and guest alleviation.

1. HOPE system design
2. Spaceplane system design
3. Powered lift aircraft performance
4. Advanced aircraft evaluation technique
5. Gust wind tunnel technique

[Captions of photos not reproduced]

Figure 2. Low-speed wind tunnel spaceplane model
Figure 3. Wind tunnel model of joined wing airplane

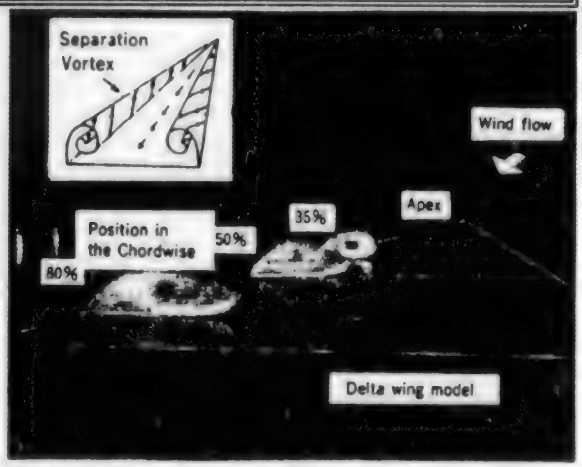


Figure 1. Surface Flow Pattern of a Delta Wing

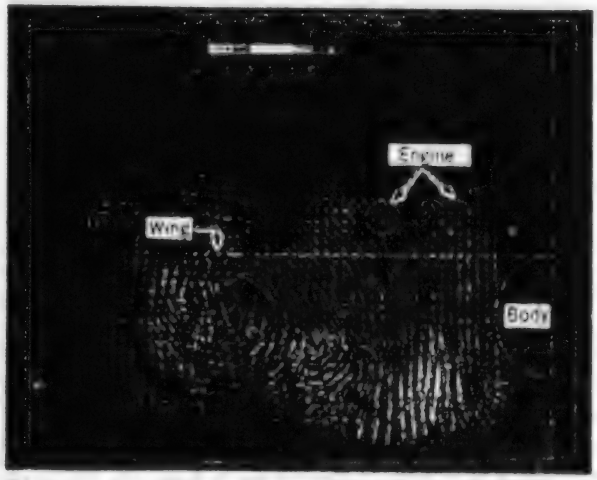


Figure 4. Wake Visualization of OTW Aircraft

Space Technology Research Group

Organization

```
                    --Group No. 1 (Planning and Engineering)
                    --Group No. 2 (Space Transportation System)
                    --Group No. 3 (Spacecraft System)
                    --Group No. 4 (Manned Space Activity Support System)
                    --Group No. 5 (Rendezvous Docking System)
Space Technology----Group No. 6 (Space Energy System)
Research Group------Group No. 7 (Electric Propulsion System)
                    --Group No. 8 (Large Space Structure System)
                    --Group No. 9 (Space Life Science Experiment System)
                    --Group No. 10 (Space Technology Experiment System)
                    --Group No. 11 (Space Lubrication System)
                    --Group No. 12 (Attitude Control System of Spacecraft)
                    --Group No. 13 (Reliability of Space System)
```

Major Areas of Research

The Space Technology Research Group conducts advanced research over a wide range of technologies necessary for future space activities.

- Basic spacecraft bus technologies
- Utilization of space environment and satellite systems research
- Other particular research areas are as follows:

1. Controlled ecological life support systems
2. Xenon ion engine systems
3. Dynamics/control of large space structures
4. Spacecraft attitude control systems
5. Thermal propulsion systems
6. Space tribological systems
7. Space energy systems
8. Space manipulator systems

[Captions of photos not reproduced]

Figure 1. Ring cusp type xenon ion thruster
Figure 2. Testing of ball bearings in an ultrahigh vacuum
Figure 3. Rice cultivation experiment in a closed system
Figure 4. Target capture experiment by space robot

Kakuda Research Center--Rocket Propulsion Research Division

Organization

Rocket Propulsion Research Division	---Rocket Engine Systems Lab. ---Rocket Combustor Lab. ---Rocket Fluid Systems Lab. ---Rocket Altitude Performance Lab. ---Rocket Propellant Lab.

Major Areas of Research

The Rocket Propulsion Research Division conducts research on the LO_x/LH_2 rocket engines, which are the fundamental type of rocket propulsion, and on its advanced rocket engines to establish technologies for construction of high-performance and long-life engines. Small rocket engines for space propulsion and energy conversion materials are studied as well.

1. LO_x/LH_2 rocket engine research
   - Research on high-pressure combustor
   - Research on long-life combustor
   - Research on advanced turbopump components
   - Research on long-life bearings and seals for turbopump
   - Research on evaluation of turbine materials
   - Research on engine health monitoring
   - Research on numerical simulation of flow in rocket engine components

2. Advanced rocket engine research
   - Research on dual-fuel combustor
   - Research on air-augmented rockets
   - Research on slush hydrogen

3. Space propulsion research
   - Research on orbital maneuvering system (OMS) rocket engine
   - Research on ultraminiature rocket pump

4. Energy conversion materials research
   - Research on evaluation of total conversion efficiency
   - Construction of functionally gradient materials (FGM) database

[Captions of photos not reproduced]

Figure 1. Test of rocket pump inducer
Figure 2. Test of cryogenic bearing and seal for turbopump of LO_x/LH_2 rocket engine
Figure 3. Slush hydrogen generator
Figure 4. Test of orbital maneuvering system engine

Kakuda Research Center--Ramjet Propulsion Research Division

Organization

Ramjet Propulsion Research Division	--Ramjet Performance Lab. --Ramjet Combustion Lab. ---Ramjet Structure Lab. --Ramjet Aerodynamics Lab.

Major Areas of Research

The Ramjet Propulsion Research Division conducts research on system and component technologies of the scramjet engines which will be the main propulsion system of the spaceplane in the hypersonic region. Engine test techniques in hot hypersonic airstream and heat-resistant structures using functionally gradient materials are also studied.

1. Design, fabrication and test of a subscale water-cooled scramjet engine

2. Scramjet engine system research

   - Research on engine performance
   - Research on multimode propulsion systems

3. Scramjet engine component research

   - Research on supersonic combustion
   - Research on cooling and structure
   - Research on nozzles
   - Research on inlets

4. Ram/scramjet engine testing technique research

   - Construction of the ramjet engine test facility
   - Research on high enthalpy shock tunnels

5. Research on thermo-structures made of functionally gradient materials

[Captions of photos not reproduced]

Figure 1. Test of thermo-structure model of leading edge for scramjet
Figure 2. Supersonic wind tunnel test of scramjet inlet with a fuel injection strut
Figure 3. High altitude test of scramjet nozzle

Cooperation With External Organizations

International Cooperative Research

NAL is conducting many cooperative research [projects] with the following foreign organizations.

Organization	Subjects
IAR (Canada)	Two-dimensional transonic airfoil tests
CSA etc. (Canada)	Microgravity fluid flow experiments
NASA (U.S.)	• Participation in dynamics of solid earth • Information exchange on CELSS
ESA (Europe)	Spaceplane technology
NLR (Holland)	Computer application technology
DUT (Holland)	Aircraft identification and control
FFA (Sweden)	• Transonic aerodynamics research • Strength and stiffness of advanced composite structures
DLR (Germany)	• Hypersonic airbreathing engine • Functionally gradient materials • Space solar energy technology

NAL is also a participant of the VAMAS (Versailles Project on Advanced Materials Standards).

Domestic Cooperative Activities

- **Domestic Investigation Commission (AIC)**

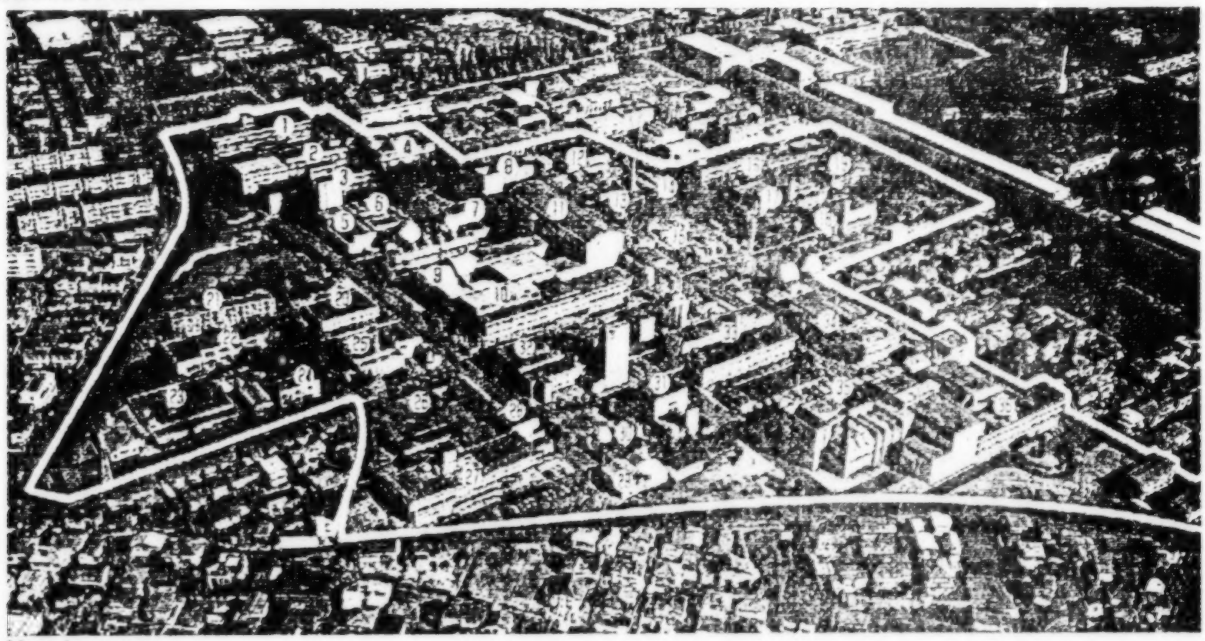
  NAL provides technical support for aircraft accident investigations performed by AIC.

- **Japan Aircraft Development Companies (JADC)**

  Recent aircraft, such as the Boeing 777, have been manufactured in the framework of international cooperation. JADC is a participant of the cooperation and NAL is providing technical support.

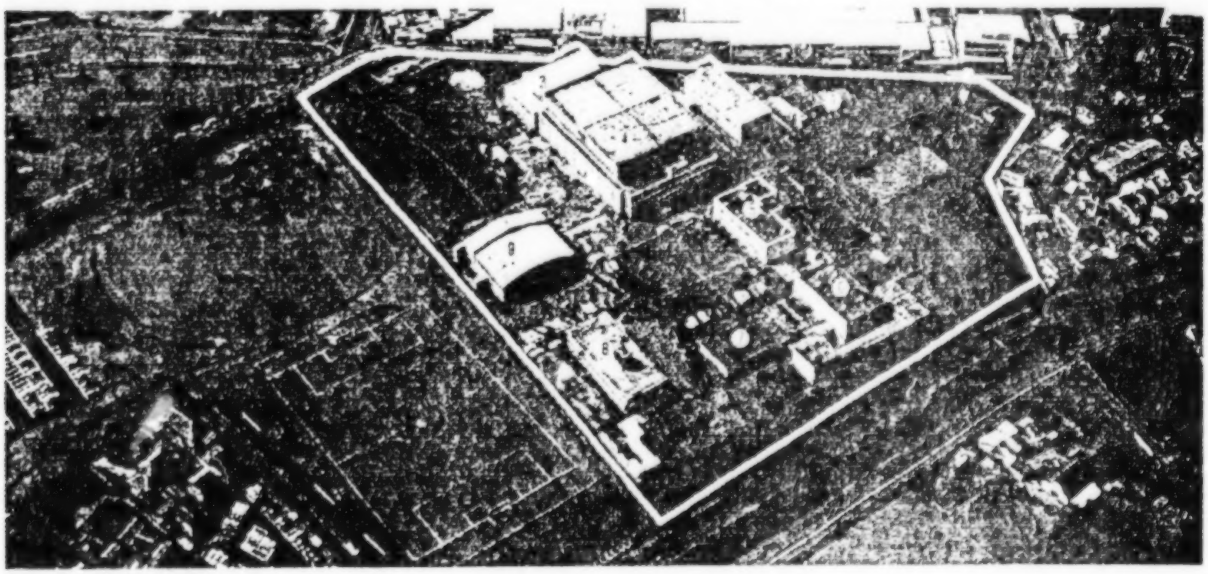
- **Cooperative Research Activities**

  Research and development in the field of aeronautical and space technology necessitate large-scale test facilities. NAL operates the largest test facilities in Japan, which are also utilized by universities as well as private companies.



Headquarters

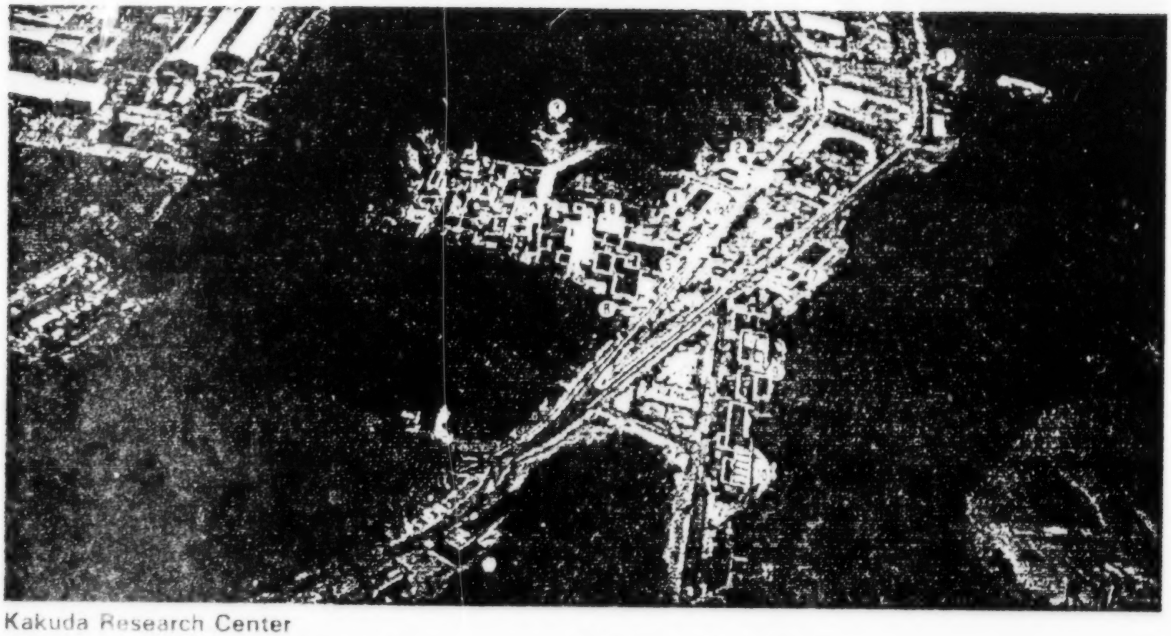
1. Administration Bldg.
2. Structural Mechanics Bldg. No.1
3. Structural Mechanics Bldg. No.2
4. Control Systems Bldg. No.1
5. Blowdown Supersonic Wind Tunnel
6. Flutter Testing Wind Tunnel
7. Two-Dimensional Transonic Wind Tunnel
8. Two-Dimensional Transonic Wind Tunnel (Compressor Room)
9. Transonic Wind Tunnel Test Section
10. Aerodynamics Bldg. No.2
11. Transonic Wind Tunnel (Driving Section)
12. Aeroengine Bldg. No.7
13. Electric Power Substation
14. Boiler Room
15. Electric Power Supply Facilities
16. Aeroengine Bldg. No.1
17. Aroengine Bldg. No.2
18. Aeroengine Bldg. No.3
19. Aeroengine Bldg. No.4
20. Library
21. Dormitory
22. Cafeteria
23. Workshop
24. Computational Sciences Bldg. No.2
25. Computational Sciences Bldg. No.3
26. Computational Sciences Bldg. No.1
27. Control Systems Bldg. No.2
28. Flight Simulation Center
29. Ion Engine Test Facilities
30. Space Technology Lab. No.2
31. Space Technology Lab. No.1
32. Aeroengine Bldg. No.6
33. Aeroengine Bldg. No.5
34. Hypersonic Wind Tunnel
35. Large-Scale Low Speed Wind Tunnel
36. Aerodynamics Bldg. No.4



Chofu Airfield Branch

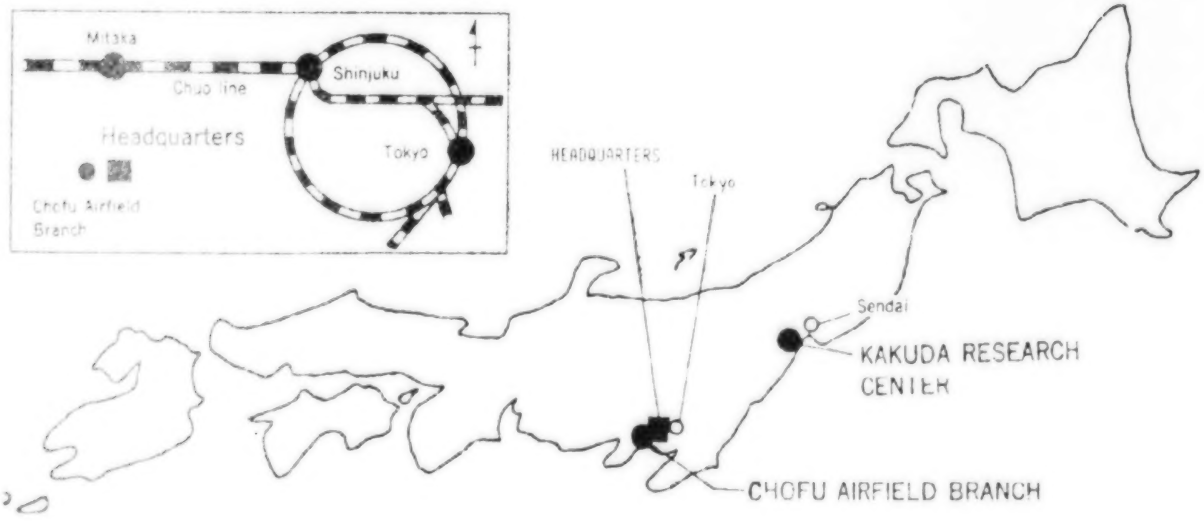
1. Electric Power Substation
2. Composite Structure Testing Facility Bldg. No.1
3. Composite Structure Testing Facility Bldg. No.2
4. Airframe Bldg. No.1 and Full-Scale Structure Testing Facility
5. Advanced Aircraft Bldg. No.2
6. Gust Wind Tunnel
7. Advanced Aircraft Bldg. No.1
8. Flight Research Bldg. No.1
9. Hanger

Facilities



Kakuda Research Center

① High Pressure Liquid Oxygen Turbopump Lab.
② Administration Office
③ Propellant Lab.
④ Computer Center
⑤ Ramjet Bldg. No. 1
⑥ Ramjet Bldg. No. 3
⑦ Turbopump Lab.
⑧ High Altitude Test Lab.
⑨ Liquid Hydrogen Rocket Lab.
⑩ Liquid Propellant Rocket Lab.
⑪ Ramjet Bldg. No. 2



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